FLORIDA POLYTECHNIC UNIVERSITY

Capstone Design

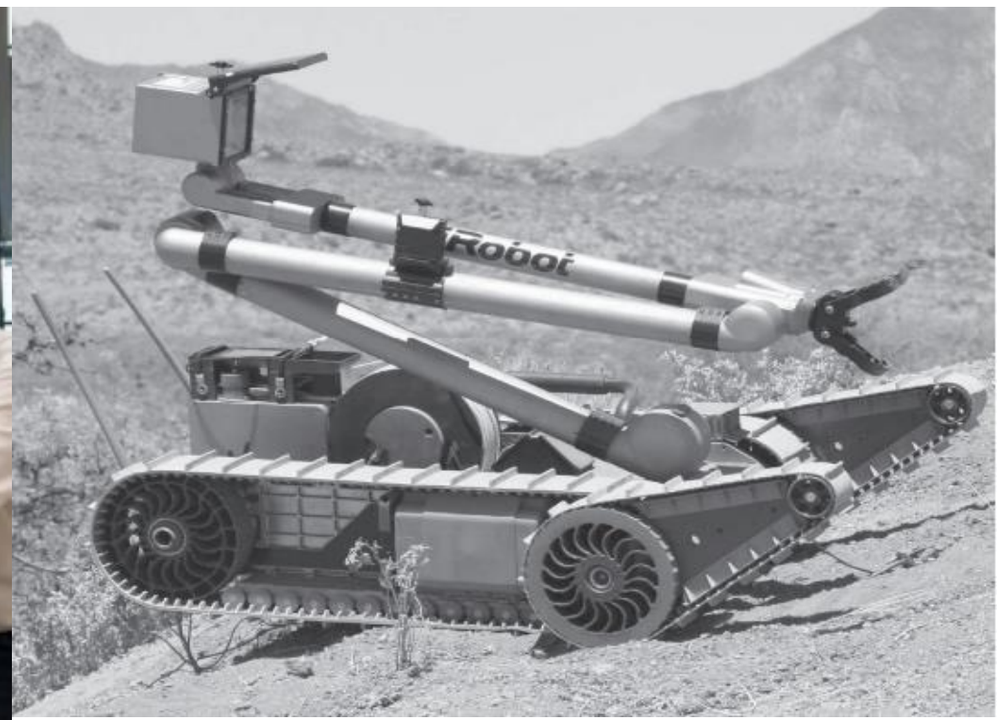
Prototyping - When, why, and how.

M. Bohm, Fall 2024

What is Prototyping?

Broad Overview

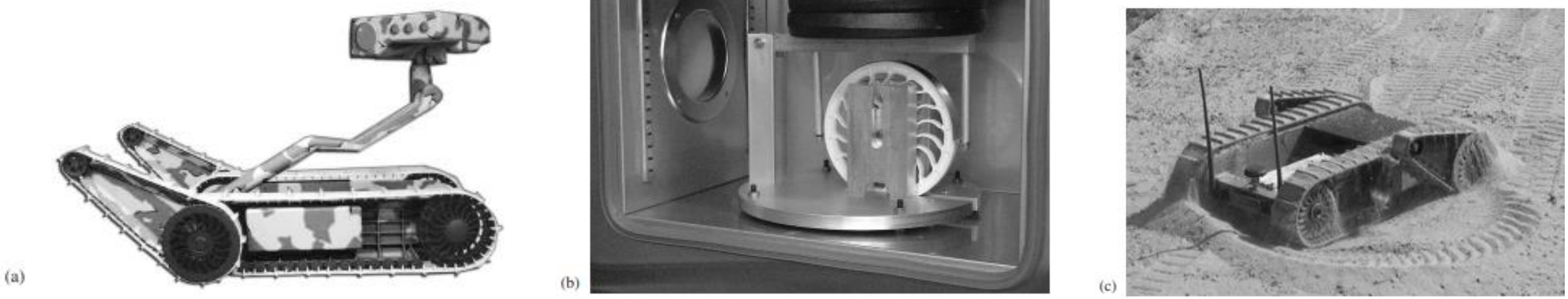
- Prototyping is essential in the design process, providing a tangible or virtual representation of concepts to explore functionality, usability, and feasibility.
- Prototypes can range from low-fidelity sketches to high-fidelity, fully functional models.



Four Types of Prototypes

Type 1: Physical Prototypes

- Tangible approximations of the product, often used in mechanical, electrical, civil, industrial, and cybersecurity engineering.
- Allows for interaction and testing of physical properties and user interfaces.



(a) Examples of physical prototypes of the PackBot. (iRobot) Looks-like model for customer communication and approval, (b) wheel prototype under load during creep testing, (c) sand test of the complete system.

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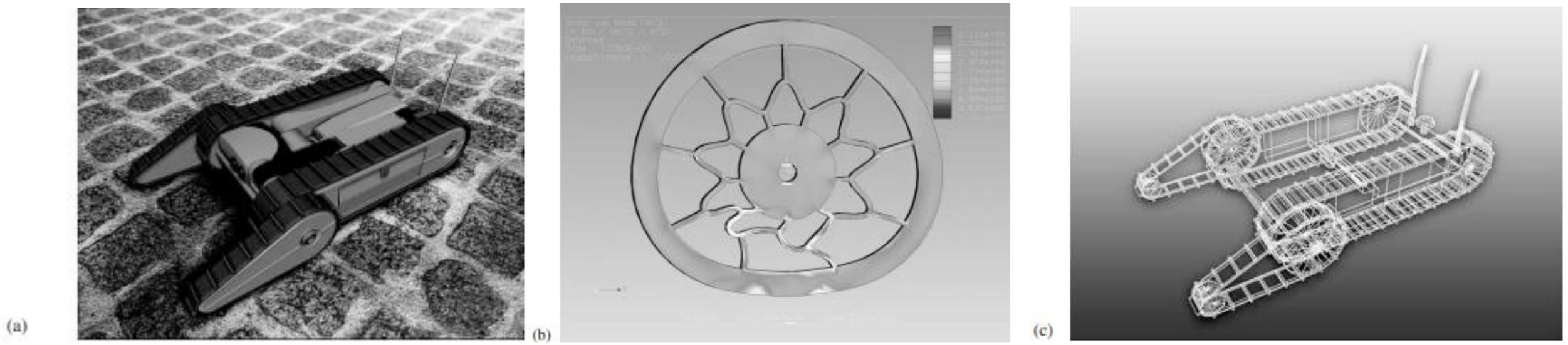
Four Types of Prototypes

Type 2: Analytical Prototypes

- Mathematical models and simulations, used in data science, business analytics, and applied mathematics.
- Helps predict behavior and performance without physical models.



Examples of analytical prototypes of the PackBot. (a) 3D CAD rendering created for a customer proposal, (b) finite element analysis of wheel spoke geometry, (c) dynamic simulation model.

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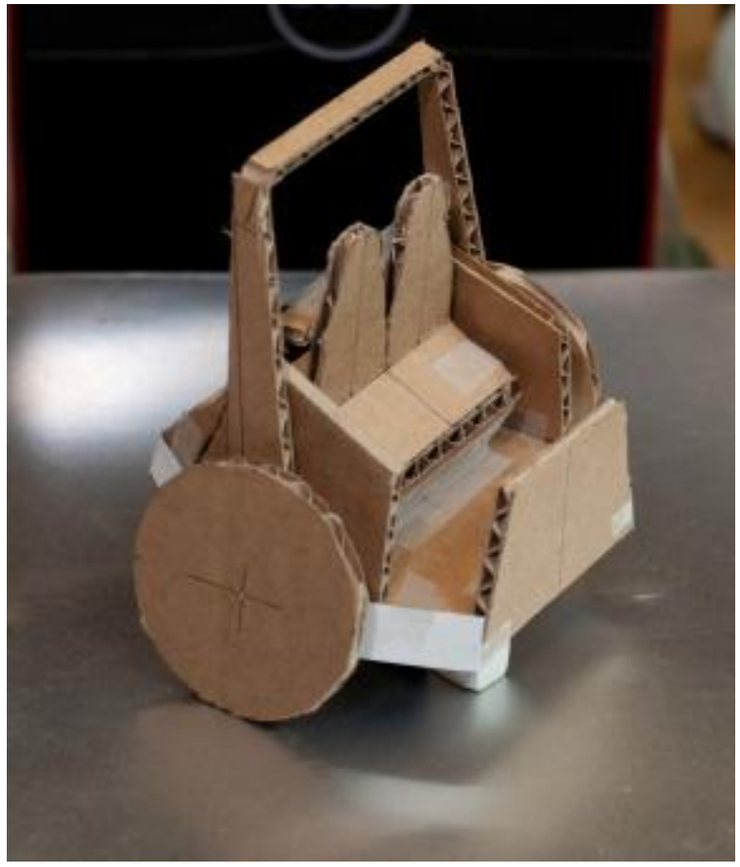
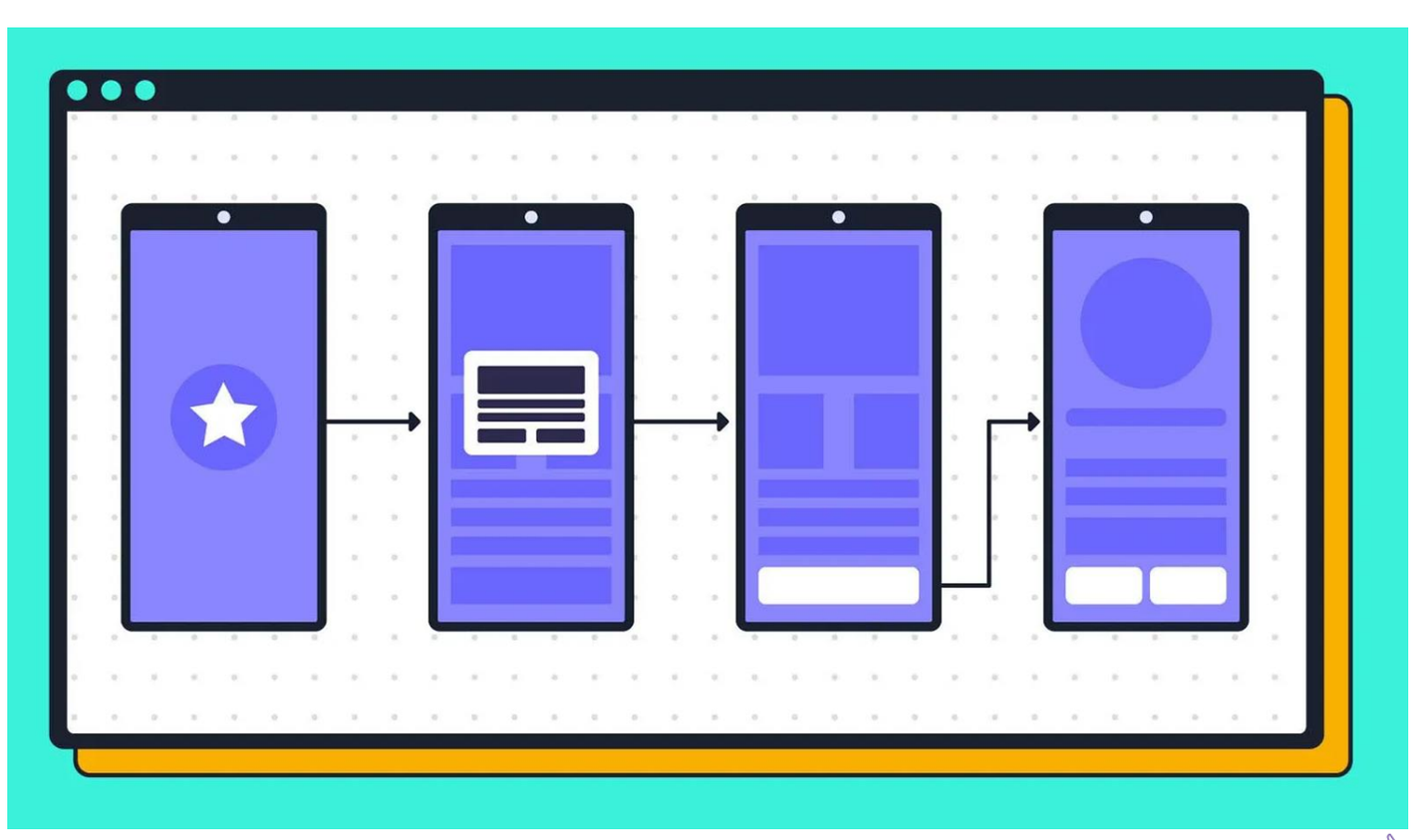
Four Types of Prototypes

Type 3: Focused Prototypes

- Targets specific features or aspects of a design, requiring multiple iterations to cover the entire product space.





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Four Types of Prototypes

Type 4: Comprehensive Prototypes

- Integrates multiple aspects into a full-featured model, typically used later in the design process for final validation.

Comprehensive prototype of a 2018 McLaren P1

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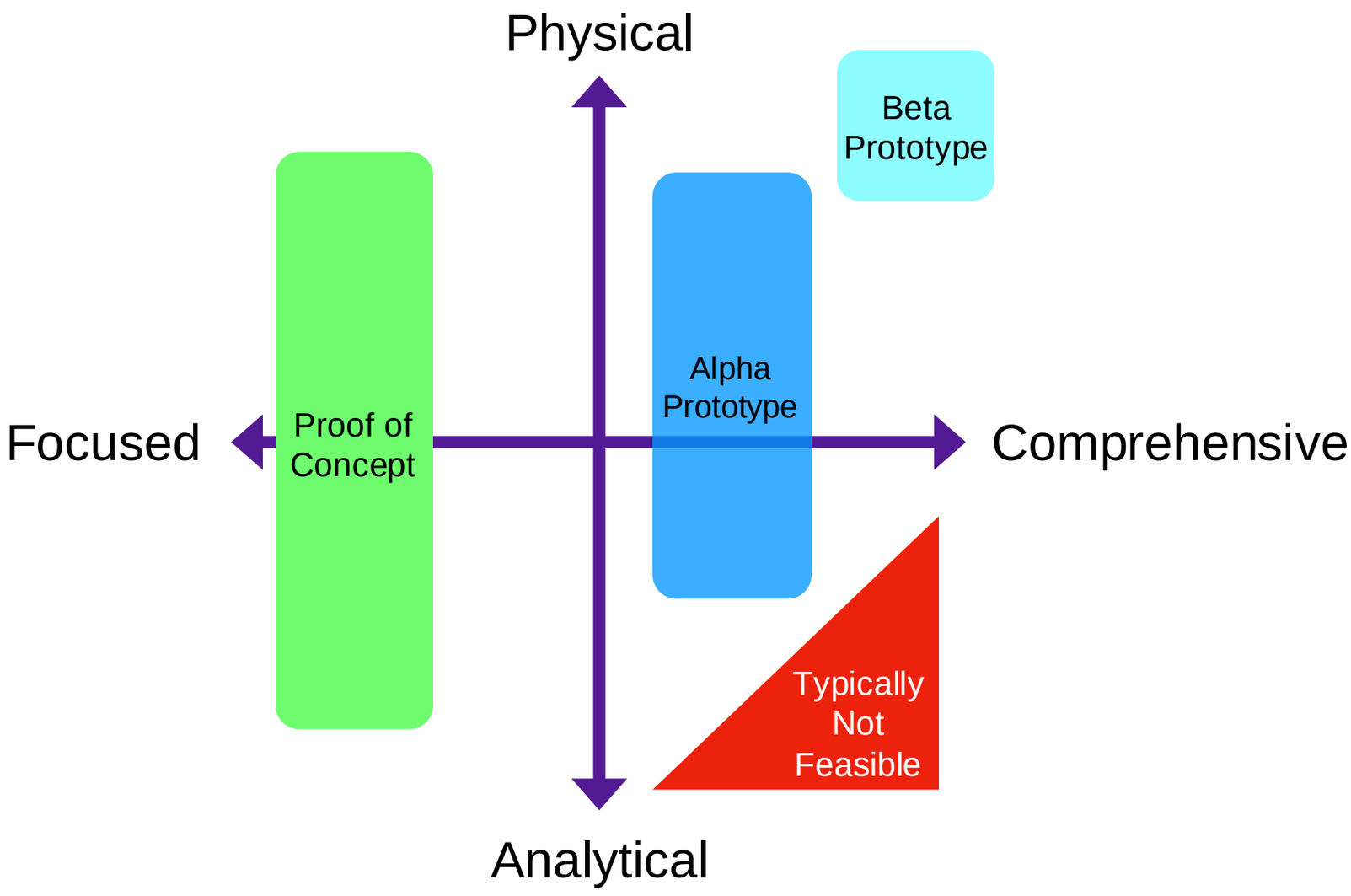
The 4 Types as Axes

The 4 Quadrants



Physical Prototypes: Applications in mechanical, electrical, civil, industrial, and cybersecurity engineering.

Analytical Prototypes: Models and simulations for data science, business analytics, and applied mathematics, as well as engineering.

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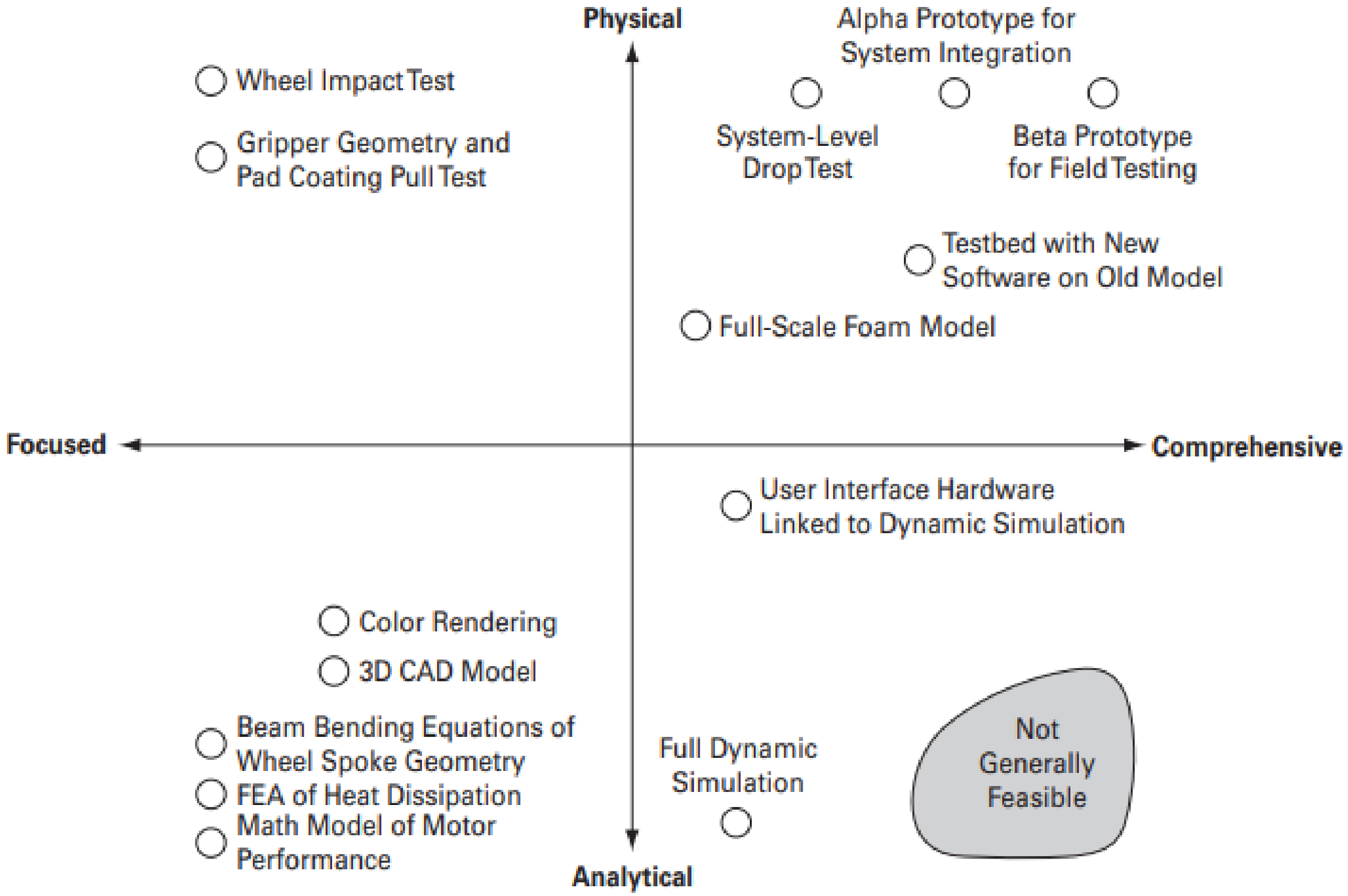
Different Prototypes for Different Reasons

The 4 Quadrants Again



George E. Dieter and Linda C. Schmidt.
Engineering Design, 4th edition. (2009).

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The Purpose of Prototypes

Mapping Prototypes to Purpose

	Learning	Communication	Integration	Milestones
Focused Analytical	✓	✗	✗	✗
Focused Physical	✓	✓	✗	✗
Comprehensive Physical	✓	✓	✓	✓

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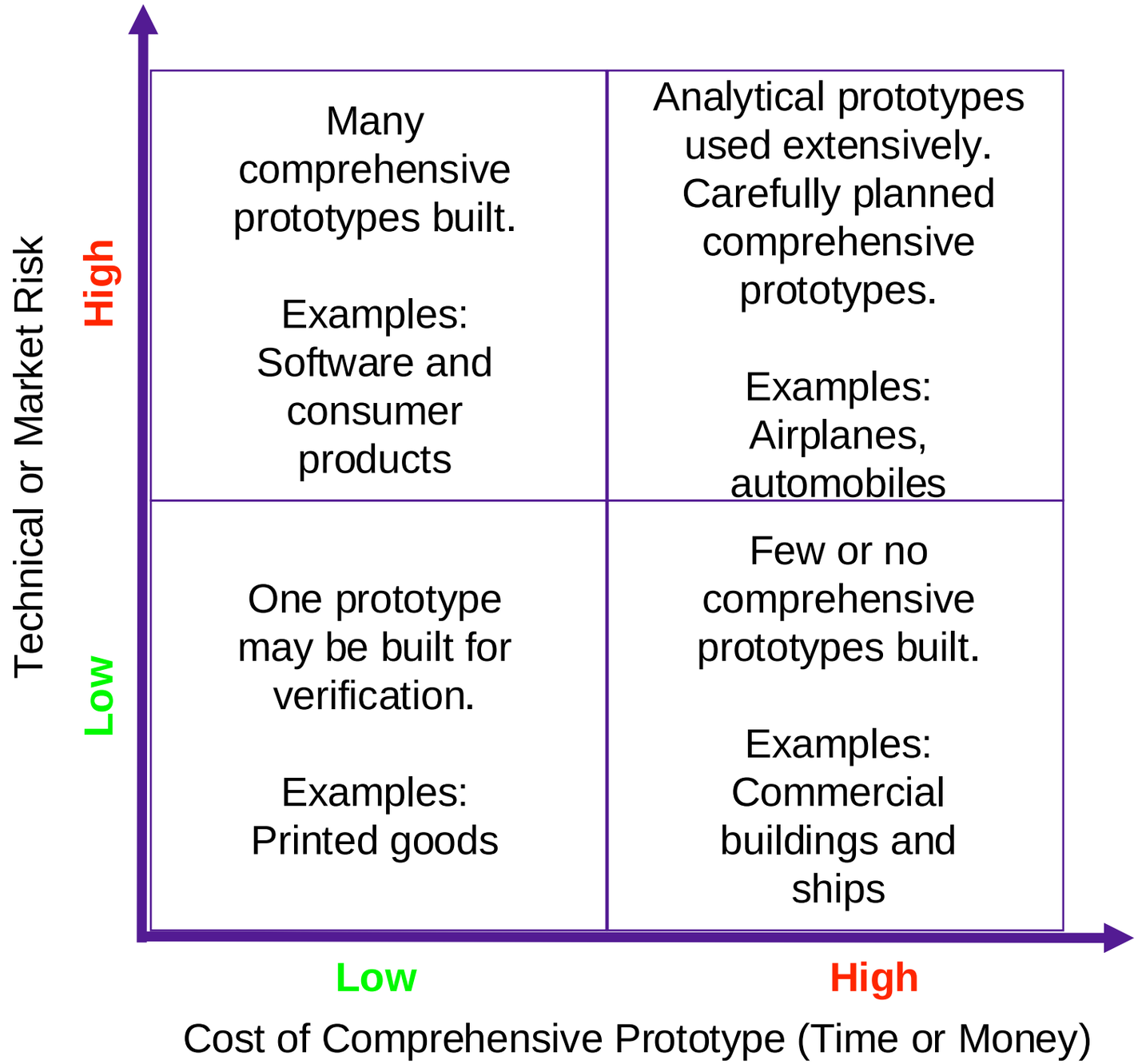
Prototype Risk vs. Cost

Mapping to Time, Cost, and Risk


Technical or Market Risk
High
Low
Many comprehensive prototypes built.
Examples: Software and consumer products
Analytical prototypes used extensively. Carefully planned comprehensive prototypes.
Examples: Airplanes, automobiles
One prototype may be built for verification.
Examples: Printed goods
Few or no comprehensive prototypes built.
Examples: Commercial buildings and ships
Low
High
Cost of Comprehensive Prototype (Time or Money)

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Examples of Prototypes

Across Different Disciplines

- Physical Prototypes
  - Examples: Scale models, electronics breadboarding, structural testing models.
  - Used to validate mechanical and electrical design aspects.
- Software Applications
  - Wireframes, mockups, and beta versions used in computer science, computer engineering, and data science.
  - Focuses on interface design, usability, and functionality.
- Analytical Models and Simulations
  - Tools like MATLAB, Python, and R are used to create simulations that predict system behavior.
  - Important in disciplines like data science and business analytics.
- Environmental Solutions
  - Prototyping for sustainable practices, such as energy-efficient systems or pollution control technologies in environmental engineering.
- Interdisciplinary Projects
  - Combines physical, software, and analytical prototypes to address complex problems across multiple fields.

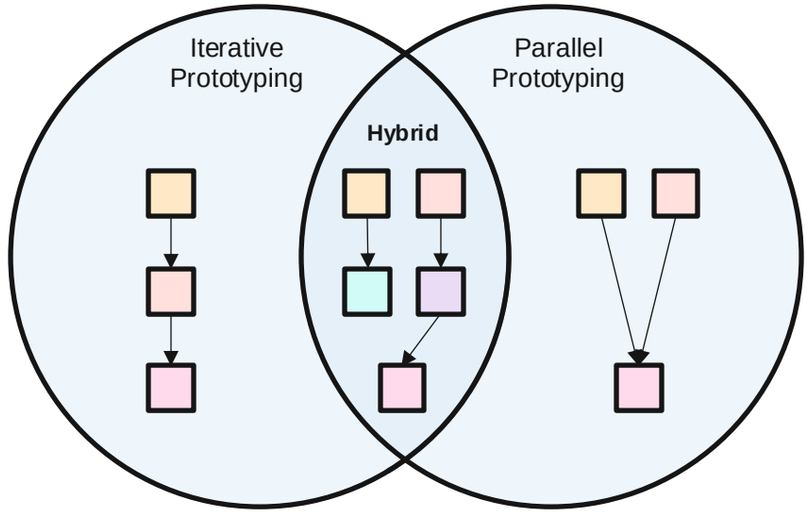
Fidelity, Cost, and Functionality

Other Angles to Consider

- Fidelity
  - Fidelity refers to the level of detail and realism in a prototype.
  - Low-fidelity prototypes, such as sketches or basic models, are useful in the early stages of design.
  - High-fidelity prototypes, like functional models, are used for detailed testing and final validation.
- Cost
  - Prototyping cost increases with fidelity and complexity.
  - Physical prototypes can be resource-intensive, while software prototypes may offer cost-effective iterations.
- Functionality
  - Functionality in prototypes can range from simple, proof-of-concept models to fully functional systems.
  - Focus on critical features that need validation to reduce development risks.

Strategies

Iterative vs. Parallel



- Iterative Prototyping
  - Involves repeatedly refining prototypes based on feedback and testing.
  - Allows designers to progressively improve the prototype, ensuring that the final product meets all requirements.
  - Common in software development and engineering projects where continuous improvement is essential.
- Parallel Prototyping
  - Developing multiple prototypes simultaneously to explore different design options.
  - Encourages innovation by allowing comparison of different approaches.
  - Useful in interdisciplinary projects where diverse perspectives can lead to better solutions.

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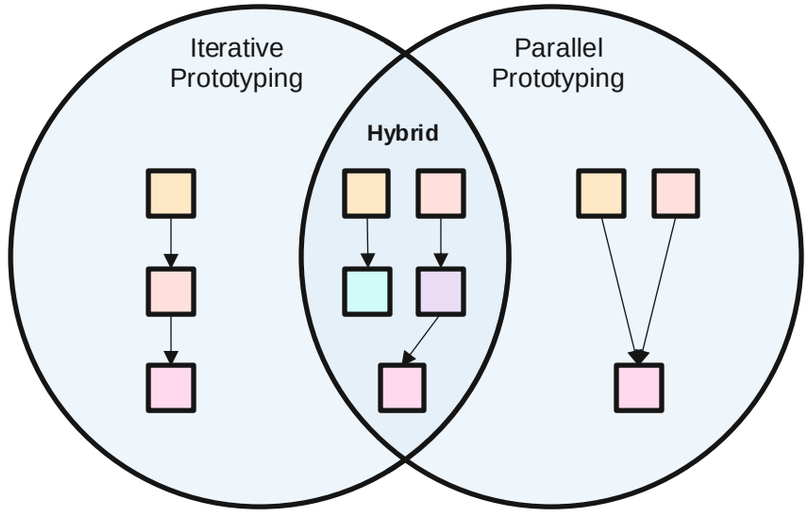
Strategies

Hybrid Approach



- Mixed Media
  - Combines physical and digital elements to create prototypes that can be tested in both real and virtual environments.
  - Example: A mechanical component tested physically while its control system is simulated.
- Mixed Approach
  - Uses different prototyping methods in tandem, such as combining rapid 3D printing with traditional machining.
  - Example: A product’s exterior is 3D printed for quick feedback, while internal components are machined for precision.
- Mixed Reality
  - Incorporates augmented reality (AR) and virtual reality (VR) into prototyping to visualize and interact with designs in a virtual space.
  - Example: An architectural model viewed through AR to assess its integration into a real environment.

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How to Use Prototypes

Learning and Communication

- Prototyping as a Learning Tool
  - Prototypes help identify potential design flaws and areas for improvement early in the development process.
  - They serve as educational tools, enhancing understanding of complex concepts and systems.
- Prototyping for Communication
  - Effective prototypes communicate design intent to stakeholders, including clients, team members, and end-users.
  - They facilitate collaboration by providing a clear, tangible reference point for discussions and feedback

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Why Prototype?

And Some Strategies

- Use prototypes to reduce risk/uncertainty
  - Figure out the fastest route to failure
- Reduce the possibility of failure by
  - Identify the failure modes
  - Prioritize the failure modes
  - Spend time on the most important ones
- Choose the timing of the prototyping cycle
- Create prototypes that are well defined and serve a purpose
- Consider multiple forms of prototypes

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Case Study 1

Dyson

- Dyson is renowned for its commitment to innovation, particularly in the development of vacuum cleaners, fans, and other household appliances. The company’s success is largely attributed to its use of iterative prototyping, which allows for continuous refinement and improvement of their products.
- **Prototyping Process:**
  - **Iterative Approach:** Dyson engineers create hundreds, sometimes thousands, of prototypes for a single product. Each iteration is tested, evaluated, and refined.
  - **Focus on Functionality:** Prototypes are developed to test specific features such as suction power, noise levels, and energy efficiency.
  - **High Fidelity Models:** As the design progresses, high-fidelity prototypes are built to closely mimic the final product, allowing for comprehensive testing and validation.

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Case Study 1

Dyson cont.

- **Impact:**
  - This rigorous prototyping process has led to the creation of highly innovative products, such as the Dyson Cyclone V10 vacuum and the Dyson Air Multiplier fan.
  - Dyson’s commitment to prototyping ensures that their products not only meet but exceed customer expectations in terms of performance and durability.

Case Study 2

OXO

- Oxo is a company well-known for its focus on ergonomic and user-friendly kitchen tools and household products. Their design philosophy revolves around making products that are easy and comfortable to use, which is achieved through extensive prototyping.
- **Prototyping Process:**
  - **User-Centered Approach:** Oxo's design process involves creating prototypes that are tested by real users, including those with arthritis or limited hand strength.
  - **Physical and Analytical Models:** Oxo uses a combination of physical prototypes and analytical simulations to ensure that their products meet the highest standards of usability and comfort.
  - **Iterative Refinement:** Feedback from user testing is used to continuously refine the prototypes, leading to products that are both functional and accessible.

Case Study 2

OXO cont.

- **Impact:**
  - The Good Grips line, one of Oxo's most successful product ranges, was developed through this iterative, user-centered prototyping process.
  - Oxo's commitment to prototyping has made them a leader in the market for ergonomic and accessible household products, earning numerous design awards.

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Case Study 3

Spotify

- Spotify, a leading music streaming service, has become a model for agile software development and prototyping. Their approach focuses on rapid iteration, continuous user feedback, and flexibility to adapt to changing market demands.
- **Prototyping Process:**
  - **Agile Methodology:** Spotify employs small, cross-functional teams known as "squads" that work on specific features or components of the app.
  - **Rapid Iteration:** Prototypes are developed quickly, tested internally, and then released to a subset of users for real-world feedback.
  - **User Feedback Loop:** Continuous feedback from users is integrated into the development cycle, allowing the company to refine and improve features before full-scale deployment.

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Case Study 3

Spotify cont.

- **Impact:**
  - This approach has allowed Spotify to rapidly innovate and release new features, such as Discover Weekly and Spotify Wrapped, which have become key differentiators in the market.
  - Agile prototyping has enabled Spotify to maintain a competitive edge by quickly responding to user needs and staying ahead of industry trends.

Prototyping Timeline

What and When

1. Proof of Concepts

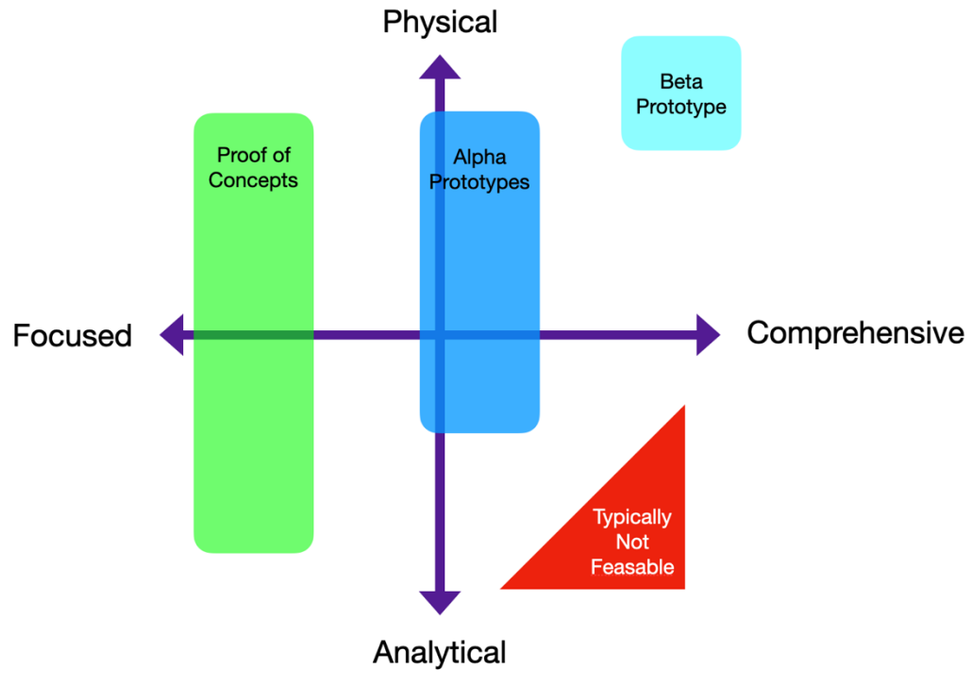
- Focused physical or analytical prototype
- Two cycles

2. Alpha Prototype

- Moving toward comprehensive and physical

3. Beta Prototype

- Full featured physical and comprehensive prototype



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